Name _____ AP Chemistry

How Galvanized is Your Washer?

Introduction

Chemistry is a measurement science. Making good observations, knowing the limitations of laboratory equipment, and understanding when data is meaningful are the traits of a good scientist. Mass and volume measurements are common laboratory measurements in chemistry. The terms precision and accuracy are often used interchangeably, but to scientists, they have two distinct meanings. **Precision** is the reproductively of a measurement or the magnitude of difference observed within a series of replicate measurements. The number of significant figures reveals the precision of a measurement. Standard deviation are computed as a means to gauge the precision of a series of measurements—the smaller the standard deviation, the greater the precision. **Accuracy** is how close a measurement comes to the real or actual value. Accuracy requires a known standard or careful calibration of an instrument. A common depiction of these two concepts is a bull's eye where the center circle is the "correct" or most accurate value. Figures of merit associated with accuracy are percent error and percent deviation (from the true value).

In this experiment, you will assume the role of an employee of an engineering consulting firm that has been contracted to write specification for nuts, bolts, and washers for the military. The military specifications must include a specific thickness of zinc coating for these fasteners. Fasteners are galvanized, i.e. coated with zinc, to prevent corrosion of the underlying metal. The common metal used in fabricating fasteners is steel, an alloy of iron with small quantities of carbon (0.2-2.1%) added to harden the iron. Other elements such as manganese, chromium, vanadium, and tungsten can also be added as alloying agents. The different alloys are manufactured to vary the hardness, tensile strength, and ductility of the metal. Corrosion, an unwanted electrochemical process, results from the metals reacting with water and oxygen to produce metal oxides, e.g. rusting. Rust can be prevented by coating the alloy with a more active metal such as zinc. Two processes for coating are commonly used. In the first, the object is dipped into molten zinc, i.e. "hot-dipped"; in the second, zinc is electroplated onto the object. Corrosion resistance is proportional to the thickness of the zinc coating. Typically "hot-dipped" coatings are thicker than electroplated coatings. Hot-dipped objects are preferred for use outdoors, in coastal areas, or at sea.

You will test a sample of commercially available washers to make sure they will meet the military's need for corrosion resistance as fasteners in a harsh outdoor environment. Your objective is to make precise measurements of mass and volume of several washers and to determine their density. Then you determine the thickness of the zinc coating.

Prelab Questions

1) What is the density and atomic radius of zinc? (Look online or in a reference book)
2) What are the equations for the area and circumference of a circle?
3) You weigh one washer on five different balances and then weigh five washers on one balance. Which method is more precise and which one is more accurate? Why?

Procedure

SAFETY: Hydrochloric acid—this acid is very corrosive and will cause serious burns. HCl is harmful by ingestion, inhalation, and contact with skin. HCl reacts rapidly with metals to produce hydrogen. The fumes are also harmful. Neutralize with baking soda and rinse with water if spilled.

1) Obtain five 3/8" galvanized washers. Label them with small dots of permanent marker, 1-5.
2) Measure the dimensions of one of your washers, your "master" washer, using a Vernier scale.
3) Weigh all five washers on a single balance and record the mass of each.
4) Place 10-20 mL of 3 M HCl in a 50 or 100 mL beaker in the fume hood. Then place your "master" washer in the beaker.
5) Allow the washer to completely react with the HCl. When finished, remove the washer with tongs and rinse with water.
6) Reweigh the master washer and record its mass.
7) Next, place 40-50 mL of water in a 100 mL graduated cylinder and record the volume.
8) Weigh the cylinder with water and record its mass.
9) Gently place five unreacted washers into the container. Record the new volume and mass.
10) Repeat step nine (adding in increments of five) until 30 washers have been added. Make sure that all washers are covered with water and no water is lost or spilled.

Results

Washer	**Mass (g) of Washer**
1	
2	
3	
4	
5	
Average	
Standard Deviation	

❖ Master Washer Dimension

A _____

B _____

T _____

Mass of master washer after zinc removal _____

Mass of zinc removed _____

Volume of Water (mL)	Mass of Cylinder, Water, and Washer (g)	Number of Washers
		0

Calculations

1) Calculate the average (mean) and standard deviation of your five washers weighed on one balance using either the following formula or Excel formula functions:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

where N = number of measurements and $\bar{x}$ = mean.

2) Calculate the total surface area of your master washer. There are two circular faces with a hole in the middle and two edges. Using the formula for area of surface, calculate the area of each circle (A & B diameters) and subtract the smaller area from the larger one. Then double the area as there are two faces. Next, using the formula for circumference,

calculate the circumference for each circle (A & B diameters). For the area, multiply the circumference by the thickness (T). Finally for total surface area, sum all of the areas.

3) Calculate the volume of the zinc coating in mm^3. Remember you looked up the density as an answer to the prelab question.
4) Calculate the thickness of the zinc coating in mm. Consider that volume is just area multiplied by thickness.
5) Determine the thickness of the zinc coating in terms of atoms, assuming the zinc atoms are stacked on one another. You looked up the radius of a zinc atom as part of a prelab question. Using the diameter of the zinc atoms, convert the thickness to the total number of zinc atoms.
6) In reality, zinc atoms are stacked in an "offset" pattern like oranges stacked for display in a store. This stacking pattern for atoms is called hexagonal close packed. To correct for this offset, multiply your answer in 5 by 1.25.
7) Make a plot in Excel of the combined mass of graduated cylinder (y-axis) and washers versus the volume reading (x-axis). Add a linear trendline and show both the equation and correlation coefficient, R^2, on the chart. Based on your plot, what is the average density of a single washer?
8) Calculate the density of the washers using your average mass and the volume from 3. Compare the calculated density to the one in 7.
9) Calculate the percent error for your master washer by assuming the true mass of a washer is 5.200 g. Percent error can be calculated by the following equation:

$$percent\ error = \frac{|true\ value - measured\ value|}{true\ value}\ x\ 100$$

Postlab Questions

1) If you took the washer out of the acid before it stopped reacting, how would that affect your zinc thickness results?
2) You calculated the average density of a washer two ways. Which method was more precise? Which way was more accurate?
3) Based on your calculation of the zinc coating thickness, do you think your washers were "hot-dipped" or electroplated? Why?
4) As an employee of the consulting firm, will your washer meet the standards for a harsh outdoor environment? Why or why not?

*Adapted from "How Galvanized is Your Washer?"—Bottomley, L; Bottomley, L.A.; *Chem 1310: Laboratory Manual*, 2011-2012, p 1-11.